CU Splitting Early Termination Algorithm in HEVC Intra Coding

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Abstract

High efficiency video coding (HEVC) utilizes several technology innovations to improve encoding efficiency. However, it also results in heavy computational complexity. A coding unit (CU) splitting early termination algorithm is proposed to save the encoding time of HEVC intra coding. Firstly, CU size distribution is statistically analyzed, and the CU splitting early termination algorithm for Intra coding is proposed. Then, the threshold in the proposed algorithm, which varies with the factors, CU sizes, QPs and sequences, is designed based on modified MRBD rule to achieve a better rate distortion performance. Finally, the proposed algorithm is estimated. Experimental results show that the proposed algorithm saves 31.71% encoding time on average, while it hardly deteriorates the coding efficiency.

Keywords

HEVC; Intra Prediction; Fast Coding; Minimum Risk Bayesian Decision Rule

Introduction

In order to meet the increasing demands on high definition and ultra-high definition digital video, the ITU-T Video Coding Experts Group (VCEG) and the ISO/IEC Moving Picture Experts Group (MPEG) formed a Joint Collaborative Team on Video Coding (JCT-VC) to develop the next-generation video coding standard, namely, high efficiency video coding (HEVC) [1]. HEVC adopts block-based hybrid video coding architecture, and introduces a large number of technological innovations,[2]. As a result, the compression performance is improved. However, it brings heavy computational complexity.

Many HEVC encoding algorithms fast are proposed to reduce computational complexity [3-6]. Shen et al. proposes a fast algorithm of CU size to skip some specific depth rarely used [3]. Leng et al. takes the co-located CU in the previous frame into account[4]. Sun et al. proposes a a fast algorithm with low-complexity based on CU breadth [5]. Kim et al. hasproposed an intra prediction fast algorithm, which controls 5% of False Termination Rate (FTR) to reduce complexity[6]. The above algorithms have brought false decision of the CU and rate distortion (RD) cost increment to some extent. In this paper, a CU splitting early termination algorithm is proposed. In the proposed algorithm, the CU splitting process is terminated when current RD cost is less than a threshold. The threshold is exquisitely designed based on modified minimum risk Bayesian decision (MRBD) rule.

The rest of this paper is organized as follows. Section 1 analyzes the character of video and introduces the proposed modified MRBD algorithm. Section 2 shows the experimental results. And Section 3 concludes our work.

CU Splitting Early Termination Algorithm

FIG. 1 CU SPLITTING OF THE FIRST FRAME IN BASKETBALLDRIVE SEQUENCE

CU Splitting in HM

In HEVC, quad-tree CU structure is utilized to improve the intra coding efficiency. RD optimization (RDO) processes are performed to decide the optimal CU size. RD cost is calculated by

$$J = SSD + \lambda \cdot R \tag{1}$$

where SSD denotes the sum of square difference between original CU and reconstructed CU, R denotes the total bits of a CU, and λ is the Lagrange multiplier related to QP. Generally, CU structures are mainly determined by the content of a CU. Fig. 1 shows the CU splitting results of the first frame in BasketballDrive sequence. Most of the CUs in texture

regions and object boundaries are encoded with smaller CU size. However, CUs in stationary and homogeneous regions are encoded with larger block size. Table 1 lists the statistical results of all sequences of class B when QP equals to 32. CUs are divided into two classes, split and non-split CUs. For non-split CUs, if the splitting process of these CUs could be early terminated, the computational complexity will be reduced without RD performance degradation.

TABLE 1 CU SPLITTING PROBABILITY OF CLASS B

CU size	Split (%)	Non Split (%)
64×64	87.78	12.22
32×32	58.49	41.51
16×16	29.51	70.49

Threshold Calculation Based on Modified MRBD Rule

The idea of the proposed algorithm is to classify a CU according to the current RD cost and the threshold. However, it is difficult to fully avoid error CU classification because of the complexity of CU splitting distribution. Error classification of a CU will lead to RD cost increment. In order to ensure the RD performance of video coding, the threshold is set based on MRBD rule, which can be expressed as

$$T_{opt} = \mathop{\arg\min}_{rd_{\min} \le T \le rd_{\max}} R(T) \tag{2}$$

R(T) stands for RD increase ratio when *T* is set as the threshold, which can be calculated by

$$\begin{aligned} R(T) = &\int_{k=rd_{\min}}^{T} f(k)p(w_{Split}\,|\,k)p(k)dk + \\ &\int_{k=T}^{rd_{\max}} g(k)p(w_{Non-Split}\,|\,k)p(k)dk \end{aligned} \tag{3}$$

where rd_{min} and rd_{max} are the minimum RD cost and the maximum RD cost, respectively. $p(w_{Split}|k)$ and $p(w_{non-Split}|k)$ are the posteriori probability of split CUs and non-split CUs when RD cost equals to k. $p(k)$ is the prior probability of CU with RD cost k. $f(k)$ and $g(k)$ are the increasing radio of RD cost brought by error decision, which can be described as

$$f(k) = (k - rd_s)/rd_s \tag{4}$$

$$g(k) = (rd_n - k)/rd_n \tag{5}$$

where rd_s is the RD cost of a CU when splitted into 4 sub-CUs, and rd_n is the RD cost of a non-splitted CU. To avoid that phenomenon, we must know the prior probability $p(k)$，two dimension joint distribution

$$p(w_{Split}, k) \cong p(w_{Split}\,|\,k)p(k) \tag{6}$$

$$p(w_{Non-Split}, k) \cong p(w_{Non-Split}\,|\,k)p(k) \tag{7}$$

are used and Equ. (3) is modified as

$$R(T) = \sum_{k=rd_{min}}^{T} f(k)p(w_{Split}, k) + \sum_{k=T}^{rd_{max}} g(k)p(w_{Non-Split}, k) \tag{8}$$

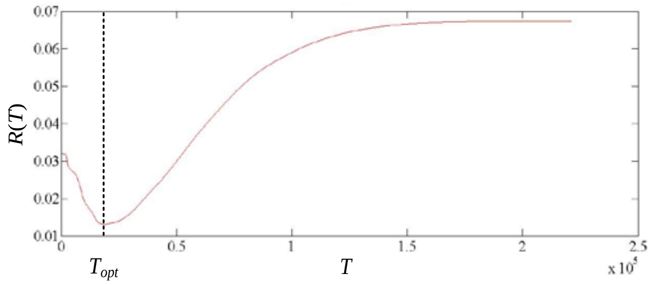

FIG. 2 R(T) VS. T

Fig. 2 shows the relation between *R(T)* and *T* when CU size is 32×32 in sequence of class B. As *T* increases from rd_{min} to rd_{max}, *R(T)* decreases firstly and then increases. The abscissa of the inflexion point of the curve is the optimal threshold T_{opt} which can be used in the proposed algorithm to achieve a better RD performance.

Resolution, QP and CU size are key factors that determine the optimal thresholds. Explorative experiments are performed on different resolution sequences, QPs, and CU sizes. The curves can be fitted to a cubic polynomial function with QP. Figs. 3(a), (b) and (c) show the optimal thresholds of sequences in Class A, Class B and Class C. For certain sequence, the threshold matrix can be calculated by

$$(Th_{64} \quad Th_{32} \quad Th_{16})^T = P \times (QP^3 \quad QP^2 \quad QP \quad 1)^T \tag{9}$$

where Th_{64},Th_{32},Th_{16} are the optimal threshold of each class of sequence，the coefficient matrix **P** can be represented by

$$\mathbf{P} = \begin{pmatrix} a_{64} & b_{64} & c_{64} & d_{64} \\ a_{32} & b_{32} & c_{32} & d_{32} \\ a_{16} & b_{16} & c_{16} & d_{16} \end{pmatrix} \tag{10}$$

where (a_i,b_i,c_i,d_i) are coefficients of corresponding threshold Th_i. The corresponding coefficient matrixes **P** of Class A, Class B and Class C are listed in table 2.

Experimental Results and Analyses

The proposed algorithm is implemented into the HEVC reference software HM9.2. The encoding experiments are performed complying with the common test environment "Intra only" [7]. 100 frames of each sequence are encoded.

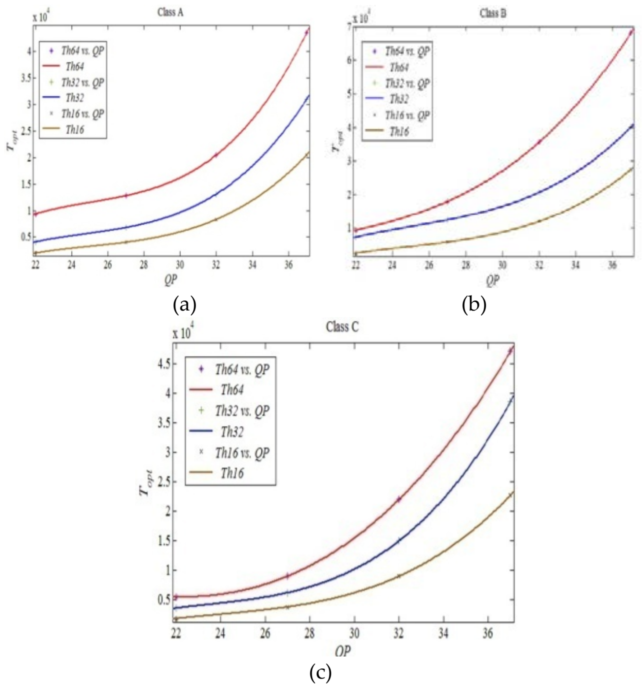

FIG. 3 THRESHOLD OF EACH CU SIZE

TABLE 2 COEFFICIENT MATRIXES OF CLASS A, CLASS B AND CLASS C

Classes	P
A	$\begin{pmatrix} 14.72 & -1107.00 & 28340.00 & -23500.00 \\ 10.53 & -780.60 & 19760.00 & -164900.00 \\ 7.35 & -548.90 & 14020.00 & -119100.00 \end{pmatrix}$
B	$\begin{pmatrix} 7.72 & -444.90 & 9597.00 & -68150.00 \\ 10.70 & -804.10 & 21100.00 & -181700.00 \\ 8.59 & -638.60 & 16430.00 & -141300.00 \end{pmatrix}$
C	$\begin{pmatrix} 3.33 & -80.00 & -1403.00 & 39600.00 \\ 11.33 & -794.00 & 18950.00 & -149600.00 \\ 7.05 & -507.10 & 12500.00 & -102900.00 \end{pmatrix}$

Comparison results are listed in Table 3 in which time saving $\Delta Time$ (%),BDPSNR (dB) and BDBR (%) are obtained by using HM as the benchmark [8].

Compared to FTR algorithm, the proposed algorithm can greatly reduce the coding time with similar coding efficiency. The proposed algorithm can achieve 31.71% coding time saving on average. Because the texture of sequence in Class C is complicated, most of the CUs should be splitted into 4 sub-CUs. Consequently, speedup performance of Class C is not as good as that of Class A and Class B. Compared to FTR, the proposed algorithm has only 0.01 dB PSNR loss or 0.24% bitrate increment.

Conclusion

In this paper, a CU splitting early termination algorithm is proposed to reduce computational complexity of HEVC intra coding. Firstly, the algorithm is proposed based on the investigation of CU splitting process and statistical analyses of the CU splitting distribution. The CU splitting process is terminated if current RD cost is not larger than a threshold. Then, the threshold, determined by resolution, QP and CU size, is designed based on modified MRBD rule to achieve a better RD performance. Finally, the algorithm is tested in terms of time consuming and encoding efficiency. Experimental results show that the proposed algorithm saves the encoding time by 31.71% while the proposed algorithm maintains high RD performance.

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TABLE 3. △TIME, BDBR AND BDPSNR COMPARISON BETWEEN PROPOSED ALGORITHM AND FTR

Classes	Sequneces	△Time(%)		BDPSNR(dB)		BDBR(%)	
		FTR	Proposed	FTR	Proposed	FTR	Proposed
A	Traffic	-25.19	-30.03	-0.04	-0.03	0.82	0.70
	PeopleOnStreet	-20.39	-28.18	-0.04	-0.05	0.77	0.88
B	Kimono	-46.63	-71.51	-0.04	-0.06	1.40	1.73
	ParkScene	-18.99	-33.86	-0.01	-0.04	0.23	0.99
	Cactus	-18.44	-31.56	-0.01	-0.04	0.38	1.26
	BasketballDrive	-40.14	-60.44	-0.02	-0.05	0.96	2.11
	BQTerrace	-21.60	-27.08	-0.01	-0.03	0.21	0.51
C	BasketballDrill	-16.22	-22.40	-0.02	-0.03	0.35	0.58
	BQMall	-14.33	-18.82	-0.02	-0.02	0.33	0.45
	PartyScene	-1.47	-3.77	-0.00	-0.00	0.01	0.03
	RaceHorces	-18.28	-21.18	-0.02	-0.01	0.33	0.23
Average		-21.97	-31.71	-0.02	-0.03	0.53	0.86

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